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Integrated graphene-based devices for optoelectronic applications

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Abstract Graphene opens up for novel optoelectronic applications thanks to its high carrier mobility, ultra-large absorption bandwidth, and extremely fast material response. Here I present novel integrated graphene-plasmonic waveguide modulator showing high modulation depth, thus giving a promising way to miniaturize the device without jeopardizing the performance of the device.

1. Abstract

In recent years, the unique optical and electronic properties of graphene attracts wide interest, ranging from light-emitting devices to photodetectors, and touch screen [1]. In particular, the opportunity to control optoelectronic properties through Fermi-level tuning enables electro-optical modulation, optical-optical switching, and other optoelectronics applications.

The deployment of graphene on top of a silicon waveguide is an efficient mean to make graphene–silicon hybrid devices [2-3]. However, it remains a big challenge to achieve high modulation depth because of the modest graphene light interaction in the graphene-silicon waveguide hybrid systems. Surface plasmon polaritons are broadband with the ability to manipulate light on the subwavelength scale [4], while at the same time giving possibility to direct more optical energy to the material interface where graphene could reside. Here I present novel graphene plasmonic waveguide modulators that are interfaced with silicon waveguides and are thus fully integrated in the silicon-on-insulator platform [5].

2. Results and discussion

Figure 1(a) shows the illustration of proposed graphene plasmonic waveguide modulator, where the plasmonic slot waveguide is coupled in/out by silicon waveguides with inverse tapering tips. The plasmonic waveguide can confine modes beyond diffraction limit, while at the same time suffering with large propagation loss. Here we propose plasmonic slot waveguides relying on the concept of leaky mode, giving us extremely low loss of 0.25dB/µm. The good alignment of the coupling part (between the silicon and plasmonic waveguide) leads to high in/out coupling efficiency of 1.45 dB.

Transmissions of the light at 1.55 µm through 20 µm-long leaky-mode graphene-plasmonic waveguides at different bias voltages are presented in Fig. 1(b) for two slot widths of 120 nm and 145 nm. One can find that the transmission through the graphene-plasmonic hybrid waveguides is effectively tuned by applying bias voltages on the graphene. An efficient attenuation tunability of 0.13 dB/µm is achieved for the plasmonic slot width of 120 nm at low gating voltages. The modulation depth of 0.13 dB/µm achieved here exceeds that for reported graphene-plasmonic hybrid device [6].

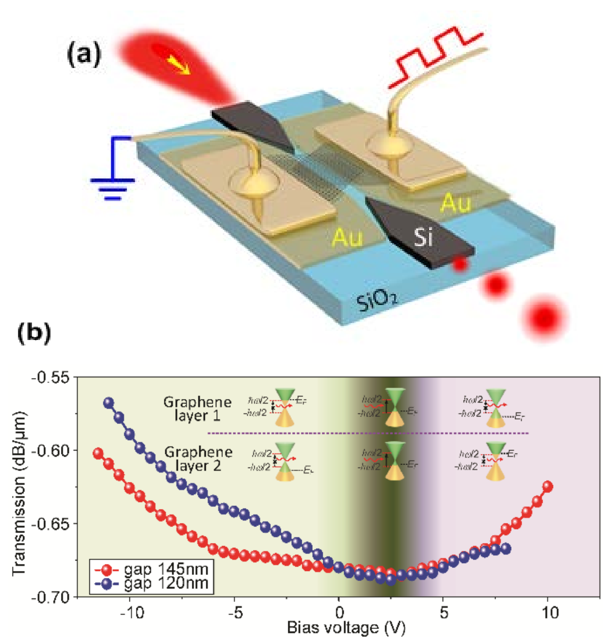

Figure 1. (a) 3D schematic of the graphene plasmonic waveguide modulator; (b) Modulated transmission for 20um-long graphene plasmonic hybrid slot waveguides.

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